An Evaluation of the Cost-Effectiveness of Gravel Application to Minimize Sediment Delivery from Forest Road Stream Crossing Approaches

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VIRGINIA DEPARTMENT OF FORESTRY

Re-opening legacy roads

Contemporary road design

Virginia road BMPs

- Location
- Grade and water control
- Surfacing of approaches

Sediment delivery at forest road approaches to stream crossings

- A primary sediment source and direct pathway for sediment transport to stream channels
- Ninth Circuit decision that ditched roads are point sources

Objectives

- Measure annual rates of sediment delivery from forest road approaches to stream crossings due to road reopening in the Virginia Piedmont.

- Compare sediment delivery rates of reopened bare approaches with existing graveled approaches and calculate gravel cost.

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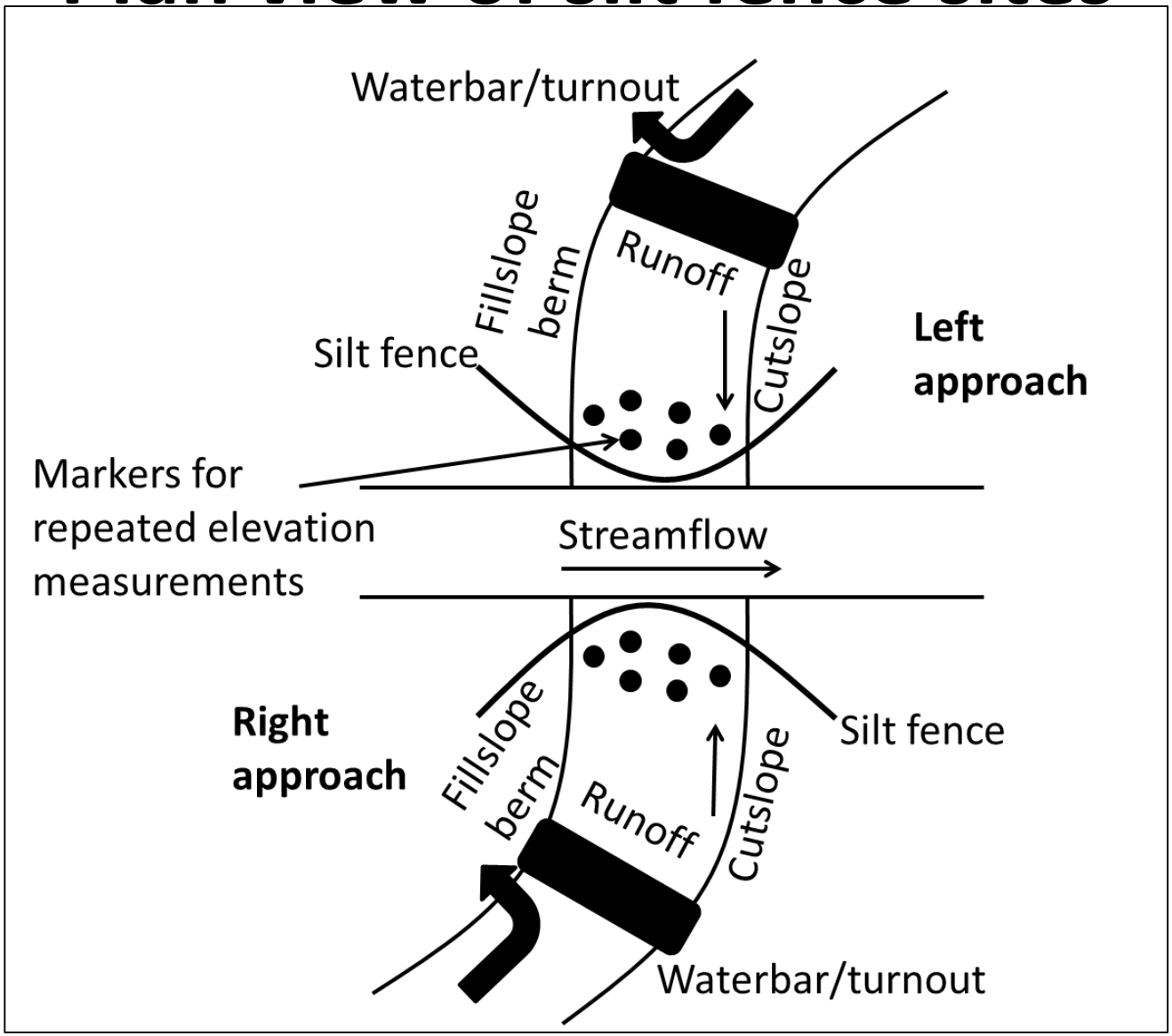
- Evaluate the sediment reduction and cost efficacy of partial and complete graveling of road approaches during storm events.

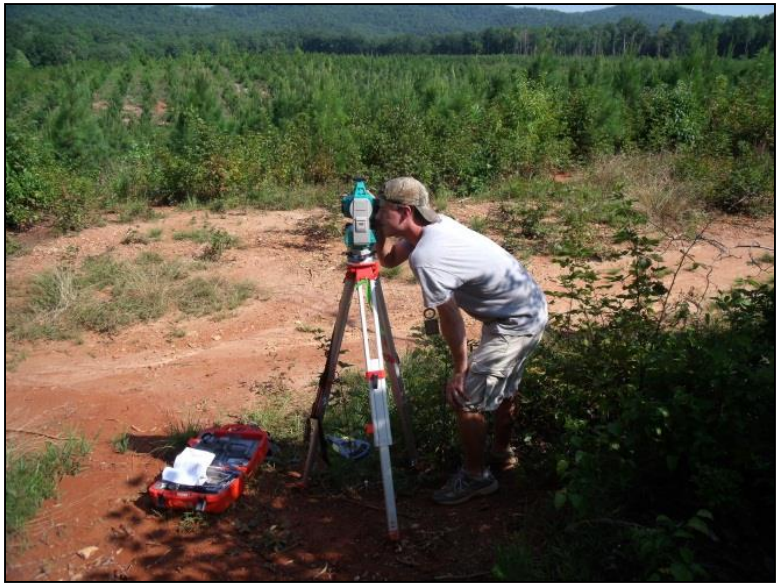
Plan view of silt fence sites



Sediment Trap Study Methods

Bulldozer blading to reopen legacy road approaches.

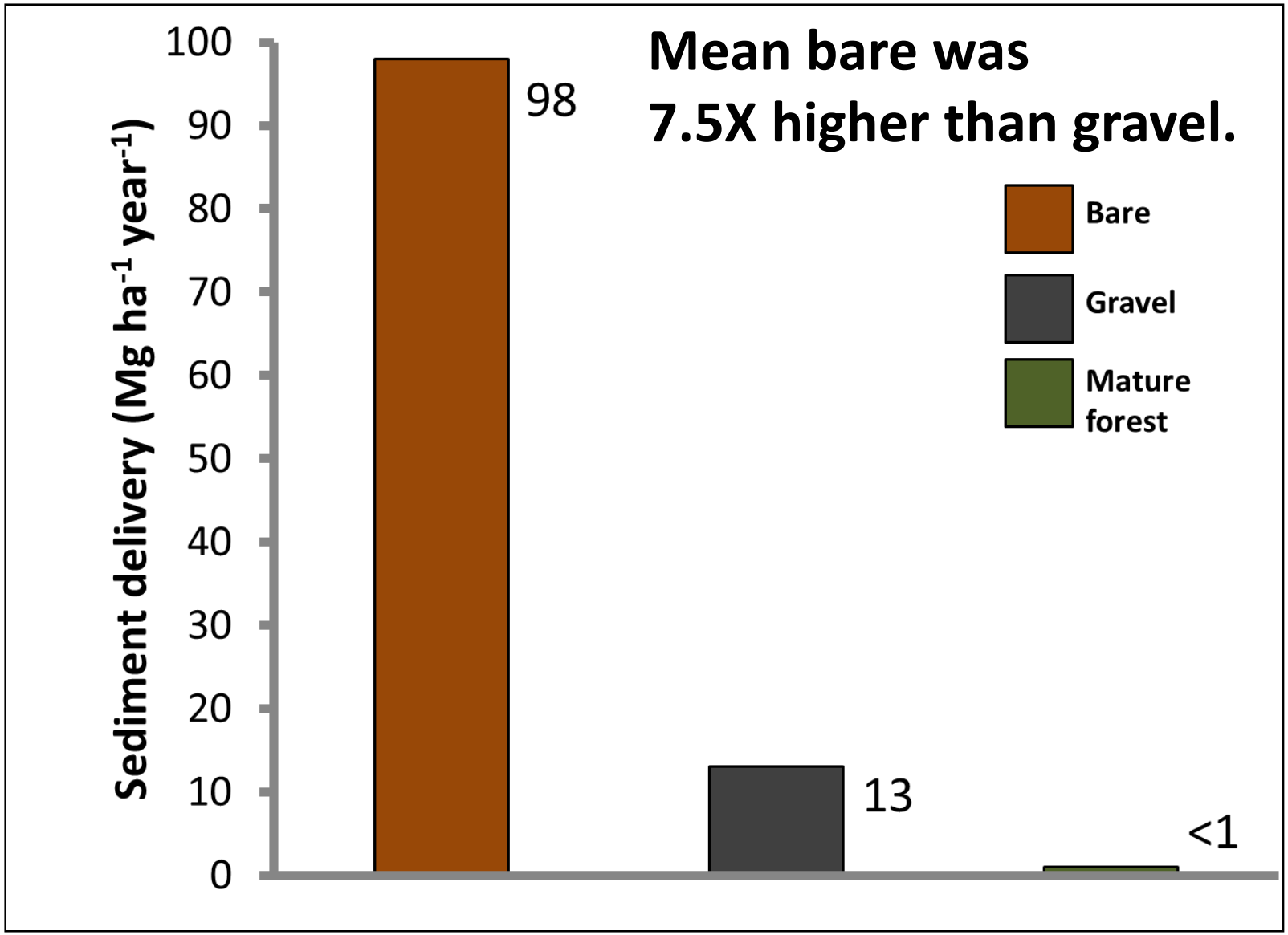
Silt fence barriers and erosion pin networks were installed to trap and measure sediment delivery.



Repeated measures via differential leveling with a total station were used to estimate annual sediment delivery rates.

Elevation gain (m) X Depositional area (m^2) X Bulk density of trapped sediment ($Mg\ m^{-3}$) = Sediment load (Mg)

Results


Mean bare was
7.5X higher than gravel.
Sediment delivery (Mg ha-1 year-1)
100
90
80
70
60
50
40
30
20
10
0
98
13
<1
Bare
Gravel
Mature forest

Gravel surfacing cost

- **Road Surface Area (m^2) X Gravel Depth (0.076 m) X Bulk Density of Crushed Rock (1.6 tonnes/m^3) X Gravel Cost ($27.5/tonne)**

- **Surfacing cost ranged from $277 to $699 and was dependent on approach length, width**

- **$3.34/$m^2$**

Problem road segments

- Surface runoff traveled between 75 and 130 m between the nearest water control structure and the silt fence

- 90 to 100% bare soil conditions throughout the year

Virginia Tech Road Cost Method

- Conrad et al. (2012) in South. J. Appl. For. (36)1
- Water control structure costs
  - Culvert + installation: $600 to $2100
  - Broad-based dip: $25 to $50
  - Water bar: $15 to $30
  - Water turnout: $10 to $25

Research objectives revisited

- Sediment delivery rates from reopening legacy roads: **34 to 287 Mg ha^{-1} year^{-1}**

- Sediment delivery rates from existing gravel approaches: **10 to 16 Mg ha^{-1} year^{-1}**

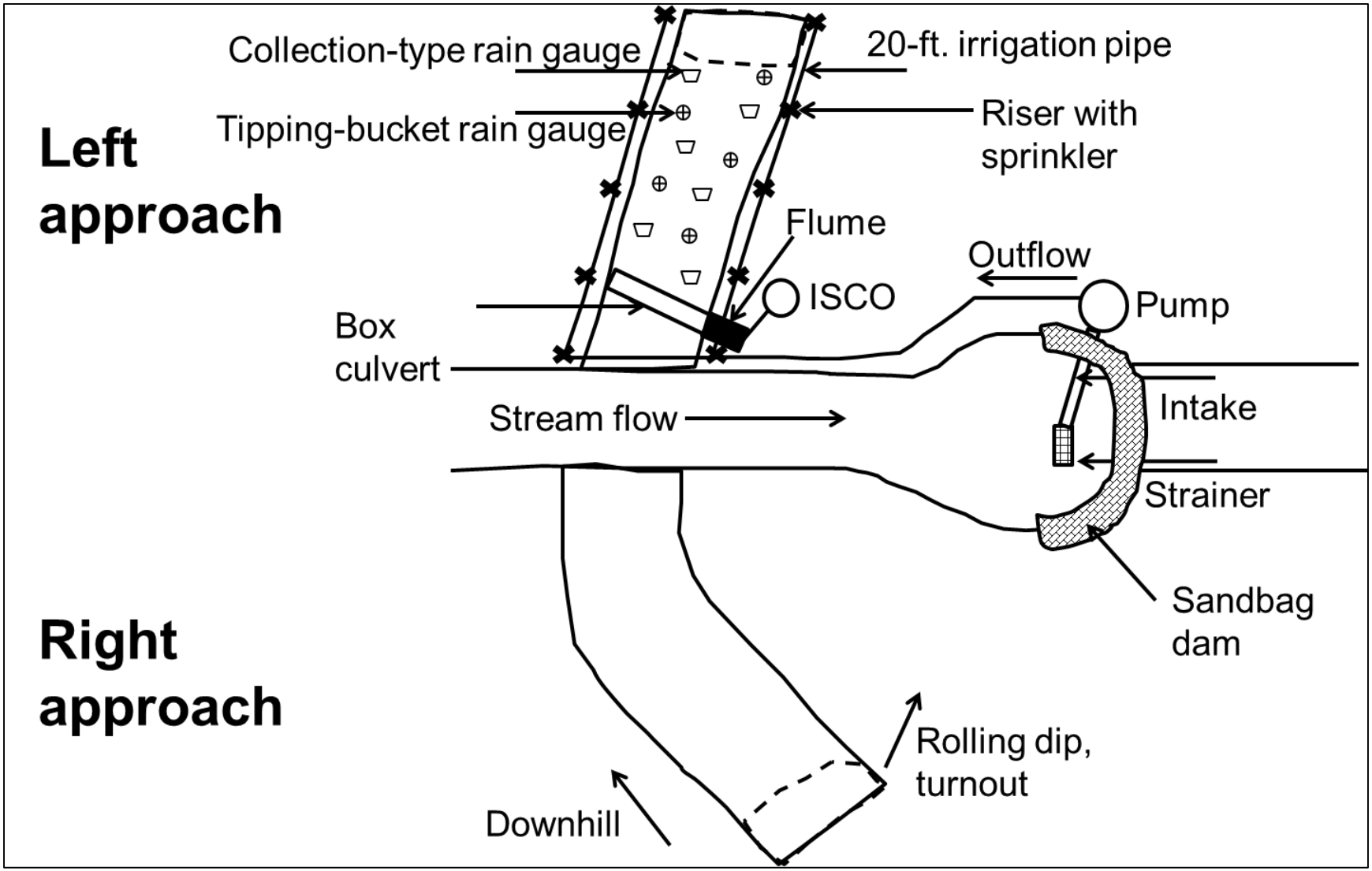
- At **\$3.34/m^2**, gravel surfacing cost: **\$277 to \$699**

Application of findings

- Legacy roads may require additional measures to minimize water quality problems.

- Findings support contemporary BMP recommendations to:
  - gravel road segments to the top of the approach that is contributing sediment to the stream
  - redistribute stormwater runoff from the road surface at least 7.6 m before the stream crossing

Plan view of rainfall simulation sites



Rainfall Simulation Methods

Bare treatment

9.8-m gravel

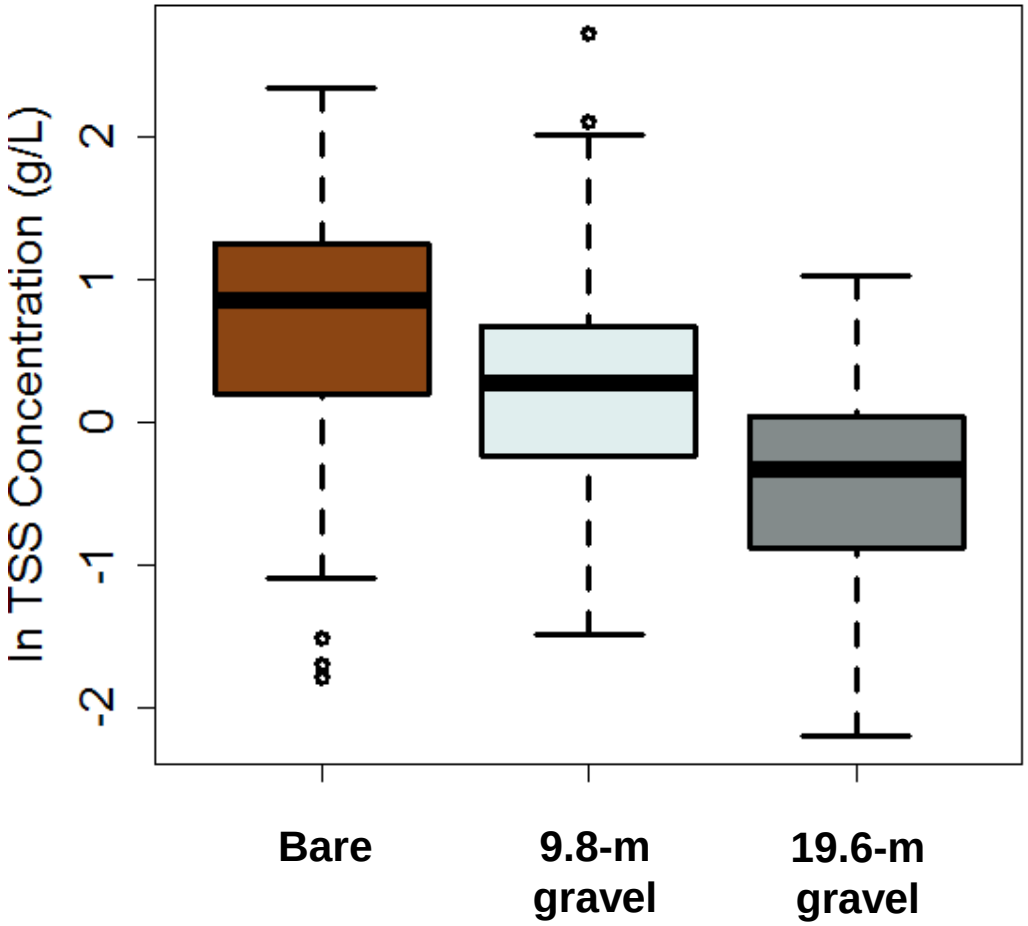
19.6-m gravel

Wedge type and automatic tipping bucket rain gauges

Open-top box culvert

1” X 18” cutthroat flume and ISCO stormwater sampler

Results



Cost effectiveness of gravel

Median TSS concentration (g L^{-1}) by treatment

- Bare treatment (2.34 g L^{-1}) was 1.8X greater than gravel 1 (1.32 g L^{-1}) and 3.3X greater than gravel 2 (0.72 g L^{-1})

Costs

- **9.8-m gravel section:** 9.8 m X 3 m X 0.076 m X 1.6 tonnes/m^3 X $27.5/tonne = **$98.31**

- X2 for the 19.6-m gravel section = **$196.62**

Conclusions

Legacy roads and associated stream crossings have the potential to deliver significant quantities of sediment to streams if the roads are not properly closed or maintained.

Corrective best management practices (BMPs), such as gravel, can minimize the sediment contributions of stream crossing approaches.

Judicious BMP implementation can reduce sediment inputs to streams and strike a balance between sediment reduction efficacy and BMP implementation cost.

Road slope lengths are difficult to correct after road construction, so careful road design is an important BMP.

Questions?